CHAPTER 7
CONCLUSION

The research work presented in this thesis focuses on improving the existing approaches in consistency checking, adaptation, synchronization and modeling of distributed multimedia presentations. The classification of the existing authoring paradigms presented by Bulterman and Hardman (2005) and the framework presented by Buchanan and Zellweger (2005) help to understand the scope and contributions of the research work presented in this thesis. The framework compares the automatic temporal formatting feature of the existing authoring tools and classifies them into compile time and run time formatters. There are also hybrid systems that perform some of the functions at compile time and some at run time. Automatic temporal formatting involves two important function: mismatch detection and the temporal layout generation.

The proposed dynamic consistency checking algorithm, with its incremental features, can revolutionise the way multimedia presentations are currently being authored. The proposed approach for consistency checking introduces the possibility of having a pre-compile time mismatch detection feature in authoring tools. This would facilitate a truly dynamic authoring environment. The layout generation is performed initially at compile time in the approach proposed in the thesis. This layout can however be regenerated during run time to support content adaptation and user interactions. The adaptation scheme and synchronization mechanism proposed in the thesis would serve as components of a run time formatter, enhancing its features and providing better response times. The research work presented in this thesis
also presents two novel approaches to model multimedia presentations effectively. The thesis presents an novel dynamic consistency checking mechanism that can be used by authoring tools to detect contradictions in the specifications during authoring. Three operators have been introduced to facilitate effective mismatch detection: a temporal operator, a spatial operator and an integrated spatio-temporal operator. The algorithm has been designed to resolve the limitations of the existing algorithm presented by Ma and Shin (2004). In addition to the simplicity, the algorithm proposed in the thesis achieved a reduction of the computation time by a multiplicative constant without changing the asymptotic value, while simultaneously introducing a dynamic approach toward consistency checking. The total time complexity of the algorithm is \(O(mn)\) where \(m\) represents constraints and \(n\) the media objects in the presentation. The response time of the prototype was used to evaluate the initial delay referred to as startup latency. The startup latency depends on the time required to resolve inconsistency, incompleteness and to compute the exact location in time and space for each media object in the presentation. The response time of the systems is thus dependent on the number of media objects and the number of constraints specified.

An approach that handles complex synchronization issues in distributed interactive multimedia presentations efficiently has also been proposed in the thesis. The synchronization control scheme uses a formal approach to model presentations at run time. The design of an extended finite state machine called communicating adaptive finite state machine (CAFSM) along with a message passing scheme which ensures synchronized play out has also been presented in the thesis. The proposed model is efficient in its time and space complexity in comparison with the existing formal approaches that define similar synchronization mechanisms. In the existing system each synchronization point is modeled as a state. For multimedia presentations that
have rapidly changing objects, there would be several synchronization points leading to several states and transitions in the existing model. The response time, in case of interactions with the presentation as well as navigations like skip, would then have a worst-case complexity, of $O(n)$, where $n$ represents the number of transitions to search from. This limitation has been resolved by the proposed design which requires only 3 states and 18 transitions to modeling any kind of presentation. The model checker SPIN has also been used to perform memory usage analysis and verification. In the proposed CAFSM model, there are only 18 transitions to search from at any point of time, leading to a system with an efficient response time to interactions. The prototype has been tested with presentations having different number of synchronization points as well as using the interaction fast-forward, rewind, pause and resume.

An efficient dynamic content adaptation mechanism built on a proxy-based architecture has also been presented. Run time formatter needs to dynamically decide which set of services to employ in order to quickly get the content into its final form. The proposed approach generates an adaptation tree dynamically for each client request in order to choose the set of services that would provide the best response time. The algorithm runs in linear time, making it more efficient than the existing approaches. The construction of the adaptation tree takes place at the client proxy, and the actual adaptation process takes place at the server proxy. This balances the content adaptation service load on either proxies. In addition to this proxy based approach, an integrated use of MPEG-21 standard that helps to perform adaptation efficiently using the digital item adaptation specification has also been presented. In a distributed environment, the traffic and the number of service requests varies from time to time. The proposed architecture places an upper bound on the delay caused due to network traffic. Every adaptation
service has a fixed service rate which is assumed to be equal for all services present. The simulation results obtained indicate that the delay would be maximum when all clients request for the same services and minimum when all clients request for different services. Since each service has a queue whose maximum length is fixed, the service will become unavailable if the number of clients requesting for that service reaches the upper bound of the queue. When this happens, the service becomes unavailable for all clients requesting this service in future. Thus the delay incurred in the completion of client requests depend upon the number of clients requesting for the same service and the number of services requested by the clients.

Layout adaptation of requested presentations which would involve adapting the temporal and spatial relationships between media objects to suit heterogeneous devices could be considered in future work. Designing dynamic interfaces to view multimedia presentations that may need to adapt to multiple simultaneous changes is a complex design issue. These adaptation requirements could either be location changes, differential scaling or semantic zooming. Incorporating these features into content adaptation mechanisms to develop better context-sensitive distributed multimedia applications would be the scope of the future work. Apart from the above, video-on-demand can be enabled whereby quality of service (QoS) can be guaranteed for different and dynamically changing usage environments by using the time-dependent metadata and scalability features of MPEG-21.

The thesis also deals with an the effective representation and modeling of the presentation specifications. An existing dynamic petri net (DPN) that can represent iterations and interactions in the multimedia presentations efficiently has been used in the thesis. However the limitation of using DPN directly is that they cannot detect inconsistency in the set of specifications
during the creation of the multimedia presentation. The dynamic consistency checking approach proposed in the thesis generates a minimum spanning tree to represent a consistent set of constraints. This minimal spanning tree approach however cannot handle iterations in the presentations. Hence, an algorithm that will automatically convert this tree into a DPN has been proposed in the thesis in order to model the multimedia presentation prior to its play out. The DPN servers as a platform to perform the verification of several other properties besides presenting a graphical view of the structure of the presentation. From the simulation results and analysis, it was found that the following three parameters had a direct impact on the response time of the converter

- The number of synchronization points.
- The number of media objects in the presentation.
- The number of intended loops.

The use of the DPN could be further enhanced to model design templates that could be merged and combined interactively with the help of the authoring tools. The thesis also present the DPN representation of two complex workflow patterns that also deal with iterations.

An approach that is based on the concept of code generation has also been used in the thesis to represent presentation specifications using a procedural approach. The use of the distributed programming model Orc has been used effectively in existing work to represent complex workflow patterns. However, in order to ensure that it represents consistent presentations, the specifications needed to be pre-processed and verified. Thus, an approach that uses the DPN initially to model and verify the specifications and an algorithm that translates the DPN into the Orc code has been proposed. The algorithm presented in this section could be extended to include several other Orc constructs to represent the other workflows as well as user interactions.
during playout.

A prototype integrating all the above features is under development. Each of the algorithms presented here have been analyzed theoretically and implemented independently. The simulation results and analysis as well as the complexity analysis have been given in the respective chapters. The need to integrate and analyze these features led to the design and ongoing development of a prototype. Several other issues are currently been taken up as further enhancements. Each of them will be integrated into the prototype eventually. The most of important of them are:

- The use of the DPN to model design templates that could be merged and combined interactively with the help of authoring tools.
- Spatial layout adaptation needs to be incorporated with the current adaptation tree. For instance, if an audio track is adapted into text, a spatial location needs to be allocated effectively for this adapted media. Also, mobile devices with varied capabilities may require the temporal and spatial layouts to be adapted to suit specific space and time restrictions.
- Appropriate retrieval policy and buffer management techniques, to handle media that need to be streamed as well as dealing with user interactions.
- A DPN player and other presentation views during authoring need to be provided

Incorporating these features into the prototype being developed would be the scope of future work.